EXECUTIVE SUMMARY

DCERP Annual Technical Report IV:
March 2010 – February 2011

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DCERP Annual Technical Report IV: March 2010–February 2011

Executive Summary

Overview

The Defense Coastal/Estuarine Research Program (DCERP) is a research-based program sited at Marine Corps Base Camp Lejeune (MCBCL) in North Carolina. This program provides a unique opportunity to integrate the results of broadly scoped, interdisciplinary ecological research to understand the structure and function of diverse and complex coastal ecosystems, while synthesizing research results to address MCBCL's management needs for sustaining the military training mission. Phase I of DCERP was successfully completed in June 2007 and resulted in the development of the *DCERP Strategic Plan*, the *DCERP Baseline Monitoring Plan*, and the *DCERP Research Plan*, which collectively serve as the foundation for DCERP activities at MCBCL. Implementation of these plans (Phase II) began in July 2007 and resulted in the establishment of more than 300 monitoring and research sites and 13 research projects. In addition, the Data Information and Management System (DIMS) was developed and currently archives DCERP monitoring and research data. The DIMS provides a standard data format that optimizes data storage and retrieval for integrated analysis, allowing for exchange of information among the various DCERP partners. Research and monitoring activities during Phase II of DCERP are currently planned for 4 years (until November 2011) in support of the minimum 10-year vision for the program. This Executive Summary highlights the Phase II accomplishments inclusive of March 2010–February 2011.

Major Highlights and Accomplishments from DCERP in 2010

Key findings/outcomes to date with implications for MCBCL management

- Five different models used to scale up nitrogen loads to the entire New River Estuary (NRE) watershed predicted that from 46% to 68% of the annual external total nitrogen load to the NRE originates from sources in the New River watershed lying off Base, with the Base contributing 9% to 20% of the nitrogen load (including 6%–9% from the wastewater treatment facility). The remaining external nitrogen load is from atmospheric deposition (5%–7%) and tidal inputs from Onslow Bay (18%–27%). The estimated loading from the five models differed slightly from the 2009 loading estimates using only one model.

- Protection of the marsh habitats that line the back-barrier of the Onslow Beach amphibious assault training area, including several splash points, may require a combination of shoreline stabilization and vessel wake controls to constrain erosion to improve sustainability of these military training areas.

- The Onslow Island shoreline has a sinusoidal morphology, with southern and northern embayments separated by a central headland. Data show that beaches around the headland in the middle of the island are steepest. There is a strong correlation between beach gradients along the island and the maximum depth of sediment erosion during a year. This is likely due to the higher wave energy that impacts steeper beaches at the headland than at low-gradient beaches at the embayments. The barrier morphology plays a more significant role in controlling the along-beach variations in beach erosion than do military training activities.

- Preliminary results suggest that both overall avian species richness (number of species) and species diversity (relative abundance of the species present) increased as the red-cockaded woodpecker (RCW) habitat quality increased. In general, these results support the hypothesis that the RCW is a good umbrella species for the management of overall avian diversity in longleaf pine habitats.

- Portions of $PM_{2.5}$ (particulate matter with a diameter less than or equal to 2.5 microns) are formed through secondary atmospheric processes (via complex heterogeneous gas-to-particle conversion reactions), whereas other portions are emitted directing into the atmosphere from various different sources (e.g., heating, wood-burning, transportation). As indicated by ozone, the proximity of MCBCL to the ocean increases the potential for atmospheric particle formation, thereby increasing the ambient $PM_{2.5}$ mass concentration. However, our findings indicate that average $PM_{2.5}$ concentrations are higher at sites farther from the ocean, suggesting that secondary (atmospheric) formation of $PM_{2.5}$ plays only a minor role in the local burden of $PM_{2.5}$ at MCBCL.

(continued on next page)

Major Highlights and Accomplishments from DCERP in 2010 (continued)

Program products transferred for immediate MCBCL use

- Maps of shoreline habitat types and estimates of shoreline erosion rates were completed for most of the Intracoastal Waterway (ICW) within MCBCL lands, complementing previous maps and erosion estimates of the mainstem NRE shoreline. These maps identify areas vulnerable to shoreline erosion and can help MCBCL develop management strategies to identify locations for erosion mitigation efforts, protect training areas, and plan for future Base development.

- With the completion of the greenness (vegetation) gain analysis, detailed information is now available regarding when a vegetation change occurred since 1984 and the change trajectory over time for all MCBCL lands. This data set can be used to assess vegetation losses or gains in terms of specific time periods or to track changes through all five change periods from 1984 to 2009.

DCERP research that confirms success of Base management practices

- Analysis of 30 years of sea turtle data collected by MCBCL revealed several important factors related to Base management of these endangered species. The relatively high proportion of successful crawls in the recreational area suggests that the Base's efforts to limit light pollution and human disturbance are being successful. The mean emergence success rate for the Base-relocated nests was also significantly higher than for natural nests in part resulting from the ability of Base staff to consistently select superior locations for relocating sea turtle nests originally laid in the military training area.

- Splash points (access points between land and water for amphibious vehicles) along the ICW eroded more from 1956–1989 (−0.44 m/yr) than from 1989–2009 (−0.20 m/yr). This reduced erosion rate is likely due to the stabilization of some of the splash points undertaken by the Base.

Key DCERP accomplishments at the programmatic level

- Researchers identified several areas where additional data or tools were needed to better understand ecosystem processes (i.e., location of the head of tide in the New River). The Strategic Environmental Research and Development Program (SERDP) provided supplemental funding to fill these data needs in six project areas.

- The Monitoring and Research Data and Information System (MARDIS) now contains more than 16-million data records. Upgrades to MARDIS included enhancements to module and project information on the public Web site and design and implementation of a Document Database for archiving final DCERP products.

- To date, DCERP researchers have six published or in-press peer-reviewed journal articles, five currently in review, and another 16 in preparation. In 2010, 23 presentations were given at various professional and scientific meetings. DCERP supports more than 40 students at our academic partners (to date, 1 doctoral dissertation and 7 master's theses have been completed).

ES-1. Background

Critical military training and testing on lands along the nation's coastal and estuarine shorelines are increasingly placed at risk because of development pressures in surrounding areas, impairments due to other anthropogenic disturbances, and increased requirements for compliance with state and federal environmental regulations. The U.S. Department of Defense (DoD) has mandated that DoD installations enhance and sustain their training and testing assets and optimize their stewardship of natural resources through the development and application of an ecosystem-based management approach.

To assist in this goal, SERDP launched DCERP at MCBCL in coastal North Carolina. MCBCL provides an ideal platform for DCERP because it

RTI DCERP Team

RTI has assembled a diverse team of experts from the following organizations, collectively referred to as the RTI DCERP Team:

- Atmospheric Research and Analysis, Inc.
- Duke University
- National Oceanic and Atmospheric Administration
- North Carolina State University
- Porter Scientific, Inc.
- RTI International
- University of Connecticut
- University of North Carolina at Chapel Hill
- University of South Carolina
- U.S. Army Corps of Engineers
- U.S. Geological Survey
- Virginia Institute of Marine Science
- Virginia Polytechnic Institute and State University

has aquatic/estuarine, coastal wetlands, coastal barrier, and terrestrial ecosystems. DCERP is a collaborative effort among SERDP, the Naval Facilities Engineering Command/Engineering Service Center, MCBCL, and the RTI International[1] (RTI) DCERP Team.

ES-2. Integration with MCBCL's Natural Resources Management

As a military installation, MCBCL has needs, or drivers, that must be satisfied to meet its readiness mission without significant disruption. These installation-specific drivers are defined by the Base's mission and geographic location, land uses to support the mission, and natural resources affected by and needed to support the mission (**Table ES-1**). MCBCL must also comply with relevant environmental laws, regulations, and guidelines, such as the federal Endangered Species Act (ESA), the Clean Water Act (CWA), and the Clean Air Act (CAA), to ensure continuance of its mission. One of DCERP's objectives is to assist MCBCL in meeting its readiness mission by providing science-based understanding and tools to assist natural resource management. Base staff were involved throughout the DCERP planning phase and participated in all planning workshops and reviewing the *DCERP Strategic Plan*, *DCERP Baseline Monitoring Plan*, and *DCERP Research Plan*. A DCERP On-site Coordinator (OSC) serves as a liaison between the Base, the RTI DCERP Team, and SERDP and coordinates and facilitates access to MCBCL lands, facilities, and database files by the RTI DCERP Team.

Table ES-1. MCBCL-Specific Military Drivers

Driver 1	Preserving the integrity of the amphibious maneuver areas, including Onslow Bay, the New River Estuary (NRE), and the adjoining training areas and airspace of the MCBCL
Driver 2	Preserving the integrity of MCBCL as a combined-arms training Base by ensuring the continued viability of its impact areas and associated training ranges
Driver 3	Enhancing future training uses of MCBCL ranges, training areas, and airspace by fully integrating the Land Use Master Plan and Range Transformation Plan
Driver 4	Ensuring that MCBCL supports all required military training activities, while complying with the Endangered Species Act (ESA) and other wildlife requirements
Driver 5	Ensuring that MCBCL supports continued military training use of the NRE, and Onslow Bay, while complying with the Clean Water Act
Driver 6	Ensuring the viability of the New River Air Station as an aviation facility through the elimination of bird and wildlife strike hazards to aircraft, while complying with the ESA and other wildlife regulatory requirements
Driver 7	Ensuring the viability of MCBCL military training activities, while supporting mission-critical infrastructure development

ES-3. Summary of the DCERP Baseline Monitoring and Research Activities

To facilitate an understanding of the ecosystem's state and dynamics at MCBCL, the following five ecosystem modules were established for monitoring, research, and modeling: the Aquatic/Estuarine Module, the Coastal Wetlands Module, the Coastal Barrier Module, the Terrestrial Module, and the Atmospheric Module. The DCERP baseline monitoring and research programs were designed to gather environmental data and support research projects aimed at addressing MCBCL's ongoing management concerns. Module-specific monitoring and research sites established during Phase II are shown on a map of the Base (**Figure ES-1**).

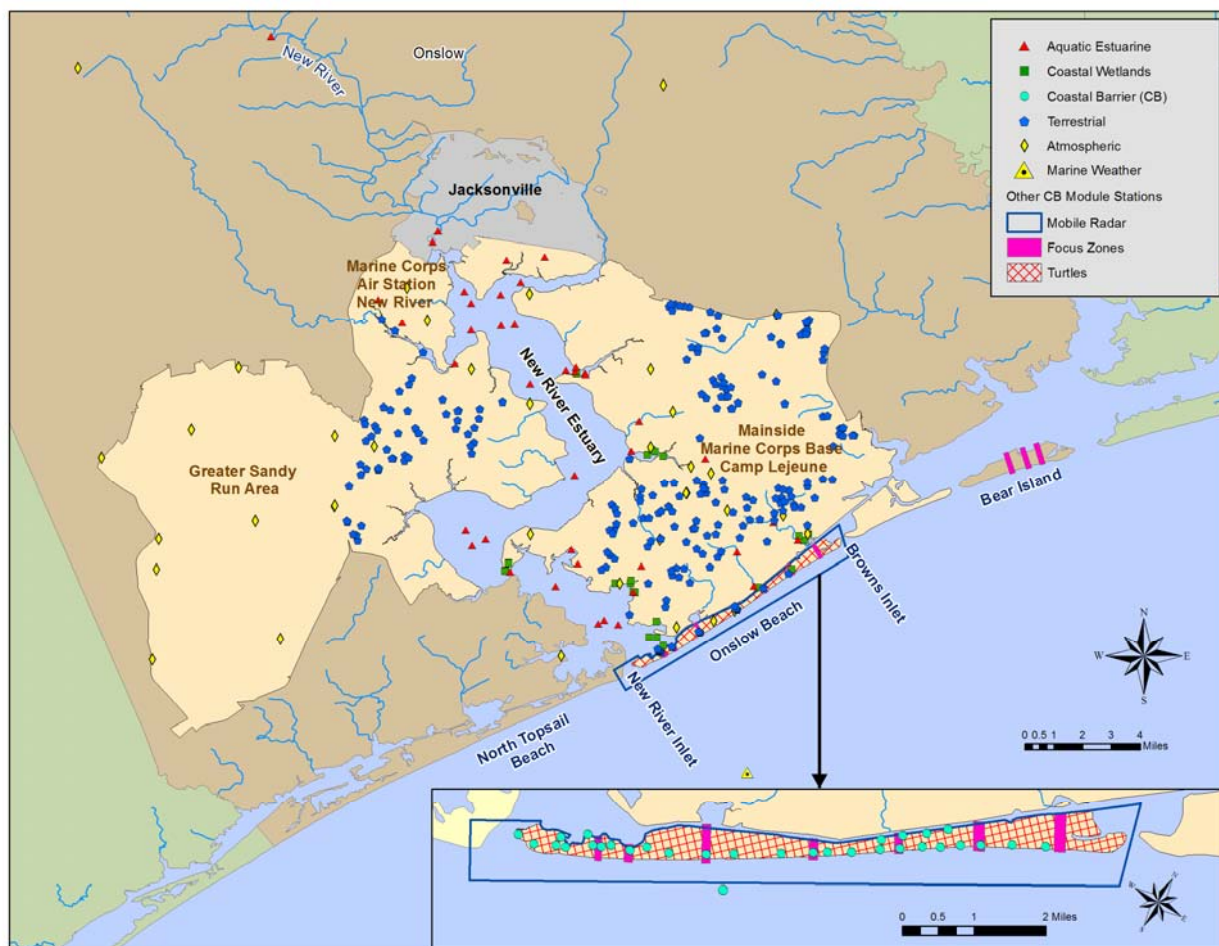[1] RTI International is a trade name of Research Triangle Institute.

Figure ES-1. Module-specific monitoring and research site locations.

DCERP was also designed to be a flexible ecosystem-based research program that is capable of adapting as additional information is analyzed from both the DCERP baseline monitoring program and within the individual research efforts. When data needs are identified, the DCERP researchers try to fill the data gaps so that the program as a whole can advance understanding of ecosystem processes. One of the major DCERP objectives is to integrate and synthesize the diverse data collected within the five ecosystems to identify linkages in the basic structure, composition, and function of the environmental system under review. Thus, DCERP adjusts to new information obtained from the monitoring and research programs and from interactions with the Base on critical management issues that need resolution to sustain the military training mission. In addition, DCERP assesses the effects of management changes through adaptive feedback loops on both the monitoring and research efforts and the ecosystem conceptual models, which are then refined as appropriate (**Figure ES-2**).
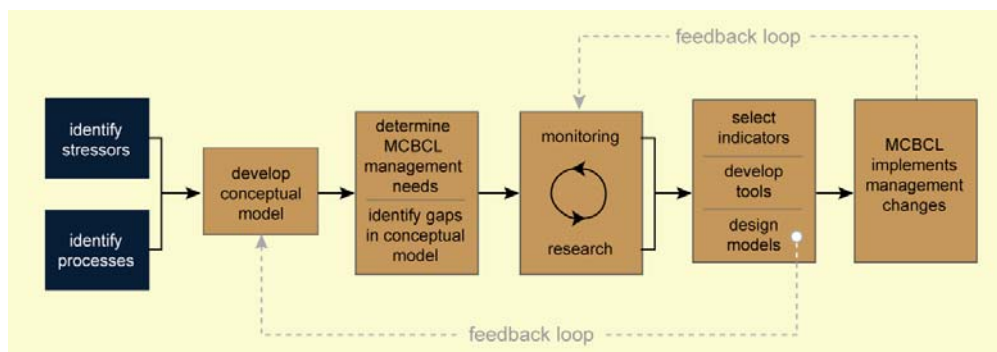
**Figure ES-2. The overall DCERP approach to ecosystem-based management
with adaptive feedback loops.**

ES-3.1   DCERP Baseline Monitoring Program

For the purposes of DCERP, baseline monitoring includes monitoring of basic (fundamental) parameters that support the broader research agendas. The DCERP baseline monitoring program is intended to be implemented for a sufficient period of time to determine the information value of each monitoring parameter. At the end of the DCERP, a cost-effective, scaled-down monitoring program will be transitioned to MCBCL so that Base staff can continue to monitor the health of the ecosystems. The DCERP baseline monitoring program is described in the *DCERP Baseline Monitoring Plan* and includes the activities listed in **Table ES-2**. All monitoring sites for the five ecosystem modules collected monitoring data during 2010.

Table ES-2. Summary of Module-Specific DCERP Baseline Monitoring Program Activities

Modules	Activities
Aquatic/ Estuarine[a]	Hydrodynamics: Stream flow and discharge (New River, NRE, and creeks) Physical/chemical: Temperature, light, salinity, pH, oxygen, nutrients, (New River, NRE, creeks) Sediment-water column interactions: Total suspended solids and sediment oxygen dynamics (New River, creeks), turbidity (NRE) Biology: Primary productivity, phytoplankton, chlorophyll fluorescence (NRE)
Coastal Wetlands	Land cover and shoreline erosion: Location, elevation, habitat types Hydrodynamics: Tide gauges (hydroperiod) Chemistry: Nutrients, salinity, hydraulic conductivity (shallow groundwater) Sedimentology: Accretion rates, organic content, particle size
Coastal Barrier	Hydrodynamics: Wave velocity, wave heights/period, currents, shoreline position, morphology Meteorology (ocean): Air temperature, wind velocity, barometric pressure, humidity, solar radiation Sedimentology: Texture, compaction, composition, sediment volume, aeolian sand transport Biology: Benthic invertebrates, fish, shorebirds/seabirds, dune/shrub/marsh vegetation, sea turtles
Terrestrial	Land cover/land use: Greenness change (vegetation gain and loss) analysis Biology: Vegetation community assessment, fuel load Soil: Soil bulk density, pH, organic matter content, mineral content
Atmospheric	Meteorology: Wind speed and direction, relative humidity, temperature, solar radiation, precipitation U.S. Environmental Protection Agency criteria pollutants: Ozone and fine and coarse particulate matter (mass)

[a] Sediment analysis, chemistry, and biology of the NRE benthic zone are characterized in Research Project AE-3.

Annually, each DCERP Module Team evaluates the spatial and temporal design of its monitoring program and assesses whether its existing program is collecting data adequate to address DCERP objectives and fill data needs. Most of the DCERP Module Team researchers indicated that the spatial and

temporal design of their monitoring programs were meeting their module's data needs and were adequate to capture variability. Ongoing assessment of the monitoring program identified some data gaps and the Terrestrial and Coastal Wetlands Module Teams were able to modify either the temporal or spatial extent of their monitoring activities. The Terrestrial Module expanded the spatial extent of its monitoring network to fill identified data gaps by increasing the number of stations from 90 to 131 to include a wider diversity of habitats across the landscape of MCBCL, including depression and pocosin wetlands and hardwood-dominated stands. The Coastal Wetlands Module increased monitoring of marsh vegetation plots to sample across a wider range of tidal elevations at each plot. Based on analysis of this data, they may extend the vegetation monitoring at each plot even further to sample the upper and lower ends of the tidal range at which *Spartina alterniflora* grows. The Aquatic/Estuarine Module Team noted that even though the NRE has yet to be impacted by a Category 2 or higher hurricane, it is evident that shifts in seasonal wet and dry periods, as well as elevated storm activity profoundly impact nutrient loads and water residence times, key factors altering biological structure and function of the estuary. The Aquatic/Estuarine Module's monitoring network detected variability in many water quality and biological parameters, but has only had a glimpse of these effects with 3 years of monitoring. Additional years of monitoring may be necessary to fully characterize and model the impact of major climatic events (e.g., tropical cyclones, major droughts) and extremes in the NRE. Similarly, the Coastal Barrier Module Team indicated its understanding of the barrier island has been limited by the absence of coastal storms of sufficient intensity to alter substantially the island morphology during the period of this study. The Coastal Barrier Module indicated that monitoring before and after episodic storm events would be useful.

Some gaps in the module monitoring programs were identified during early 2010, and several modules did not have adequate resources to improve the spatial extent of their existing monitoring network or expand monitoring to capture critical data to fill these gaps. For example, the Technical Advisory Committee (TAC) noted that the spatial extent of the Atmospheric Module's air quality monitoring program was inadequate for analyzing particulate matter and was missing critical information that would help place local airshed conditions on the Base within a broader regional context. As a result, SERDP provided funding to expand the air quality monitoring network from two to four stations to better analyze variability in fine and coarse particulate matter across Base lands. Similarly, the Aquatic/Estuarine Module researchers reported that the existing U.S. Geological Survey (USGS) New River monitoring effort was scheduled to end in November 2010, a full year before all other Aquatic/Estuarine monitoring efforts. However, New River monitoring was needed for another year to provide water quality information that captures both hydrodynamic flows and nutrient and sediment processes in the upper watershed. This information would enhance the Aquatic/Estuarine watershed modeling efforts and understanding of inter-annual variation. The TAC recommended that current monitoring be continued for another year and that additional monitoring be conducted on the New River to capture ecosystem processes occurring above the head of the tidal mixing zone not captured by the location of the existing Jacksonville stream-gaging station. As a result, SERDP provided funding to continue monitoring at the existing Jacksonville stream-gaging station for an additional year and implement quarterly surveys of the head of tide mixing zone to spatially assess flow dynamics and nutrient concentrations in the New River prior to its entering into the NRE proper. Lastly, the Coastal Barrier Module researchers indicated that the process of wind transport of sediment from Onslow Beach to the backbarrier marshes was not well understood, but this information was required to better evaluate the role of sand transport to these marshes. SERDP also provided funding for this monitoring effort, which could address questions about fate and transport of sand from collapsing dunes on the beachfront and the impact of beach vegetation on morphological dynamics of the barrier island and backbarrier marshes.

ES-3.2 DCERP Research Program

The research program was designed to increase the knowledge base and understanding of MCBCL–relevant ecosystem structure, function, and system responses to stressors and management actions and to

lead to the development of adaptive management strategies. The overall research program presented in the *DCERP Research Plan* consists of 13 separate research projects with project start and end dates as shown in **Table ES-3**.

Table ES-3. Summary of the 13 DCERP Research Projects

Research Project Title	Senior Researcher; Project Duration
AE-1: Develop and Deploy Microalgal Indicators as Measures of Water Quality, Harmful Algal Bloom Dynamics, and Ecosystem Condition	Hans Paerl; 7/2007–4/2012
AE-2: Quantifying and Predicting Watershed Inputs of Nutrients, Sediments, and Pathogens	Mike Piehler; 7/2007–11/2011
AE-3: Developing Indicators of Ecosystem Function for Shallow Estuaries: Benthic Functional Responses in the NRE	Iris Anderson; 7/2007–5/2012
CW-1: Determine Responses of Marsh Vegetation and Accretion to Relative Surface Elevation	Jim Morris; 7/2007–7/2012
CW-2: Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates	Mark Fonseca; 9/2007–11/2011
CW-3: Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands	Craig Tobias; 7/2008–10/2012
CB-1: Short-Term Barrier Evolution Related to Storms and Land Use	Jesse McNinch; 7/2009–11/2011
CB-2: Long-Term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics	Tony Rodriguez; 7/2009–3/2012
CB-3: Understanding the Top-Down and Bottom-Up Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices on MCBCL	Sarah Karpanty and Jim Fraser; 7/2007–6/2011
T-1: Effects of Different Midstory Restoration Management Options on Terrestrial Ecosystem Structure and Function	Norm Christensen; 1/2008–11/2011
T-2: Effects of Habitat Management for RCWs on Bird Communities	Jeff Walters; 1/2008–11/2011
Air-1: Optimization of Prescribed Burning by Considering Mechanical Thinning as a Viable Land Management Option	Karsten Baumann; 7/2008–12/2011
Air-2: Nitrogen Deposition to Terrestrial and Aquatic Ecosystems	Wayne Robarge; 7/2007–8/2012

Note: AE = Aquatic/Estuarine Module; Air = Atmospheric Module; CB = Coastal Barrier Module; CW = Coastal Wetlands Module; T = Terrestrial Module.

ES-3.3   Supplemental Activities

DCERP researchers can request supplemental funding from SERDP if an activity (1) needs immediate funding to prevent a negative effect on DCERP, (2) is supported by a recommendation from the TAC, or (3) fills a data gap revealed by current work or enhances work that had already been funded. In 2010, SERDP approved six activities (**Table ES-4**) that were pivotal to achieving DCERP objectives.

Table ES-4. DCERP Activities That Received Additional Funding in 2010

Title	Senior Researcher	Activity
Prototype of a Coastal Land-Use Suitability Decision-Support System for MCBCL	Pat Halpin	Data Management
Continued and New Monitoring of Discharge and Nutrient Dynamics of the New River Between the USGS Gum Branch and Jacksonville Gaging Stations	Holly Weyers and Hans Paerl	Monitoring
Shifting Sands: Examining the Contribution of Aeolian Sand to Back-Barrier Accretion, the Fate of Collapsed Dunes, and the Interactions of Flora with Island Morphodynamics	Steve Fegley and Tony Rodriguez	Monitoring
Expansion of the Spatial Coverage and Enhancements to the Air Quality Monitoring Network at MCBCL	Karsten Baumann	Monitoring
Completion of Prescribed Burning Emissions Field Experiments in Coordination with Terrestrial Module's T-1 Fuel Management Research	Karsten Baumann	Research
Completion of Additional Fuel Sampling and Analysis for the Terrestrial Module's Research Project T-1 on Fuel Management	Norm Christensen	Research

ES-4. Aquatic/Estuarine Module Summary

Estuaries integrate inputs from terrestrial, freshwater, oceanic, and atmospheric systems, and the accurate assessment and management of estuaries necessitate consideration of their connections to, and interactions with, these other ecosystems. In the context of the MCBCL region, the Aquatic/Estuarine Module examines the tidal reach of the NRE from the freshwater head of the New River near Jacksonville, NC, to the tidal inlet at Onslow Bay. The overall monitoring and research program of the Aquatic/Estuarine Module is designed to understand the complementary physical, chemical, and biotic processes that determine water and habitat quality; differentiate natural and anthropogenic ecosystem stressors (past, present, and future) at local and regional scales; take account of extreme climatic events (e.g., hurricanes, droughts); and integrate results with the other DCERP modules. The benefits of the Aquatic/Estuarine Module monitoring and research programs include providing information needed to preserve the sustainable use of the amphibious maneuver areas, including the NRE (Military Driver #1), and ensuring continued military training activities, while complying with the CWA (Military Driver #5).

Major accomplishments and benefits to the Base during 2010 include the following:

▪ When comparing a relatively wet year (2010) to a more normal year (2009) and a dry year (2008), algal bloom frequency and density were greatest in 2009, when moderate river flow was combined with significant new nutrient loads. In 2010, high discharge throughout the spring and summer supplied high nutrient loads, but also increased flushing rates (reducing water residence time in the NRE) during normal peak phytoplankton growth periods, leading to lower biomass accumulation and hence reduced bloom formation in comparison to the drier years (**Figure ES-3**). This demonstrates that hydrologic forcing (i.e., relatively high freshwater flow periods) can, at times, overshadow nutrient enrichment in the control of phytoplankton production and bloom formation, an important phenomenon for incorporation into the overall nutrient management plan for the NRE watershed and the Base.

▪ Sustained periods of dissolved oxygen (DO) concentrations of less than 4 mg/L result in hypoxic conditions known to be harmful to aquatic life. During 2009–2010, DO values of less than 1 mg/L were recorded for a total of 82 days in the New River at the Jacksonville gauging station; overall, there were 158 days with a recorded DO minimum of less than 4 mg/L. In comparing the DO results from 2010 with the two previous years (i.e., 2008 and 2009), 2010 had the lowest

percentage of days with a measured minimum DO of less than 4 mg/L at 60% as compared to 81% and 79% for 2008 and 2009, respectively.
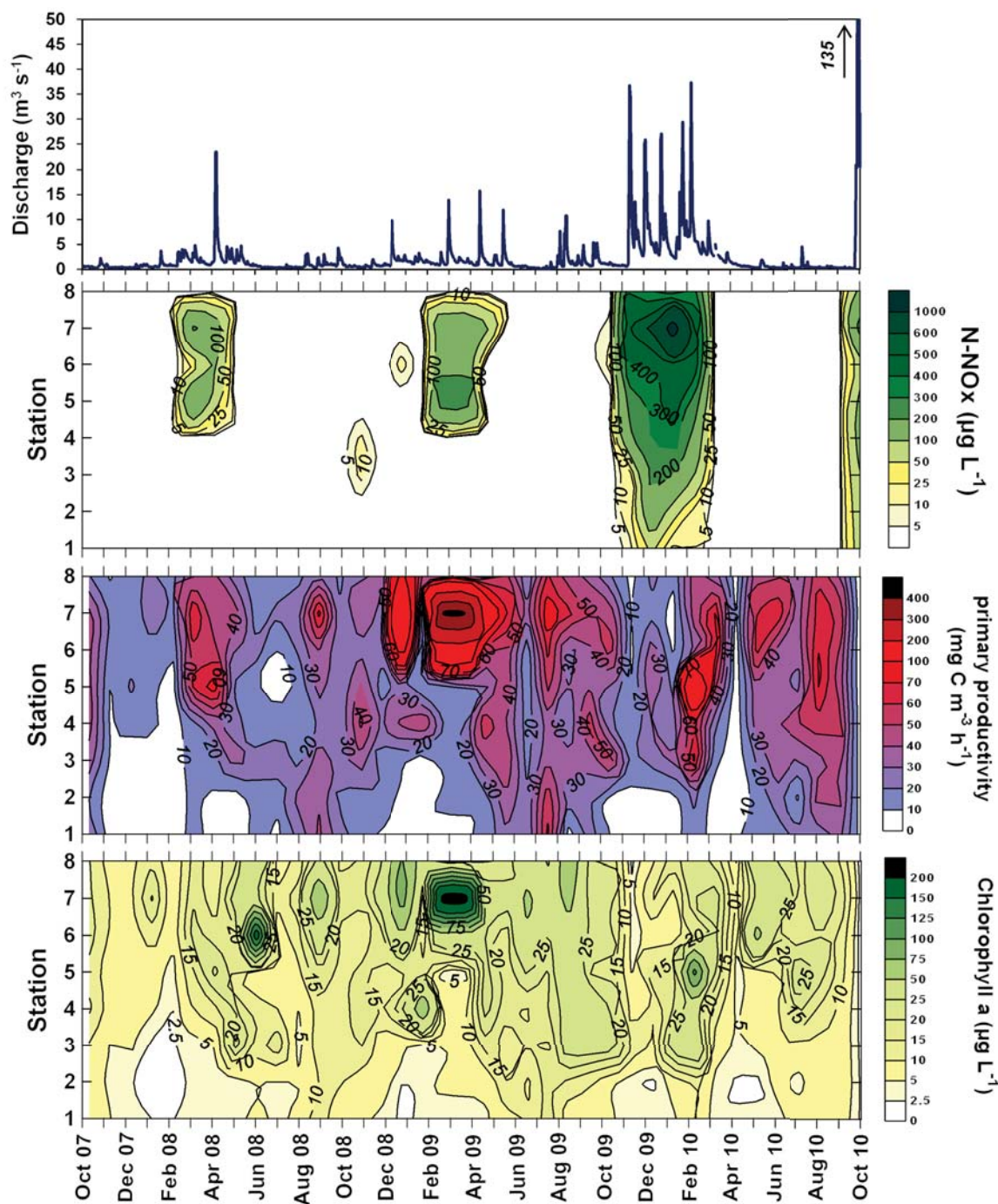

Figure ES-3. Spatial and temporal linkages of freshwater discharge, nitrate (as an indicator of watershed-based nitrogen inputs), phytoplankton primary productivity, and biomass (as chlorophyll *a* concentration) based on monthly interpolated data along the eight-station transect conducted along the axis of the New River Estuary during 2007–2010.

Station 1 is at the inlet to the Atlantic Ocean, and Station 8 is the most upstream location near where the New River enters at Jacksonville.

- Conversely in the NRE, the greatest frequency of hypoxia between 2008 and 2010 occurred in 2009, which may relate to the peak in chlorophyll *a* and particulate organic carbon (the "fuels" for hypoxia). Hypoxic conditions were distributed throughout the estuary with peak hypoxia frequencies found at mid-estuary near Duck Creek and in the upper estuary at Morgan Bay; however, the factors that drive this pattern are not yet known.

- Watershed and estuarine models that focused on the effects of nutrient loading predict that 46% to 68% of the annual external total nitrogen load to the NRE originates from sources in the New River watershed lying off Base, with the Base contributing 9% to 20% of the nitrogen load (including 6% to 9% from the MCBCL wastewater treatment facility). The remaining external nitrogen load is from atmospheric deposition (5%–7%) and tidal inputs from Onslow Bay (18%–27%). These proportions may vary, depending on inter-annual hydrologic variability. The 2010 estimate for loadings from the New River off Base differed slightly from the 75% estimated in 2009 using the Watershed Simulation Model alone. Early indications suggest that nutrient management efforts should focus on the upper New River watershed because it is a dominant nutrient source. However, future growth and development on MCBCL lands, particularly in proximity to tributary creeks to the estuary, will also need to be closely monitored as a potential "new" nutrient source. Inter-annual variability in loadings and associated hydrologic variations will be investigated further during 2011.

- In addition to phytoplankton, benthic microalgal primary production plays an important role in modulating nutrient enrichment in the NRE and can be negatively affected by disturbances such as storm water runoff events with elevated colored dissolved organic matter, thereby inhibiting the ability of the benthos to take up and retain nutrients from either the water column or sediments. We statistically analyzed potential indicators of benthic ecosystem health and found that water temperature and benthic chlorophyll were excellent predictors of benthic gross primary production.

- Mineralization rates were highest during summer and were significantly higher at Wallace Creek than at all other NRE sites, with the exception of Southwest Creek. High nitrogen-cycling rates observed at Wallace Creek are likely a response to land-disturbance activities in the upper watershed. To better detect responses to both natural and anthropogenic disturbances, a continuous monitoring program was implemented to provide information on short time-scale variability of the parameters measured and to identify the sources of that variation.

ES-5. Coastal Wetlands Module Summary

The coastal wetlands under study at MCBCL include vegetated intertidal habitats in salt and brackish waters. The health of the coastal wetlands dictates their ability to serve as a trap for sediments and nutrients (and their transformation and exchange), which improves water quality in the NRE. In addition, marshes protect the Base's infrastructure by serving as a buffer against coastal storms and compensating for sea-level rise. Salt marshes also stabilize the structure of Onslow Island through the process of sediment accretion, and therefore are essential to barrier island sustainability. The overall monitoring and research program of the Coastal Wetlands Module is designed to provide quantitative information about the condition and dynamics of coastal marshes at MCBCL and to forecast future changes in the condition of these coastal marshes due to anticipated increases in military training activities and sea-level rise. The Coastal Wetlands Module was designed to address three of the MCBCL military drivers to (1) preserve the integrity of the amphibious maneuver areas in the NRE (Military Driver #1); (2) ensure that MCBCL supports continued military training activities, while complying with the CWA (Military Driver #5); and (3) ensure the viability of military training activities, while supporting mission-critical infrastructure development (Military Driver #7).

Major accomplishments and benefits to the Base during this past year include the following:

- Shoreline areas vulnerable to erosion and areas sensitive to sediment resuspension in the NRE were identified in a comprehensive set of wave height and benthic sea floor shear stress (sediment resuspension) maps developed for the NRE tidal basin (**Figure ES-4**).

- Splash points (access points between land and water for amphibious vehicles) along both sides of the ICW eroded more from 1956–1989 than from 1989 to 2009. Compared to the mean Shoreline Change Rate (SCR) for the entire ICW from 1956–1989 (−0.44 m/yr), seven of the nine splash points had a higher mean SCR. In contrast, only four of the nine splash points had a higher mean SCR from the 1989–2009 analysis than the entire ICW (−0.20 m/yr). This reduced erosion rate is likely due to the stabilization of some of the splash points undertaken by the Base.
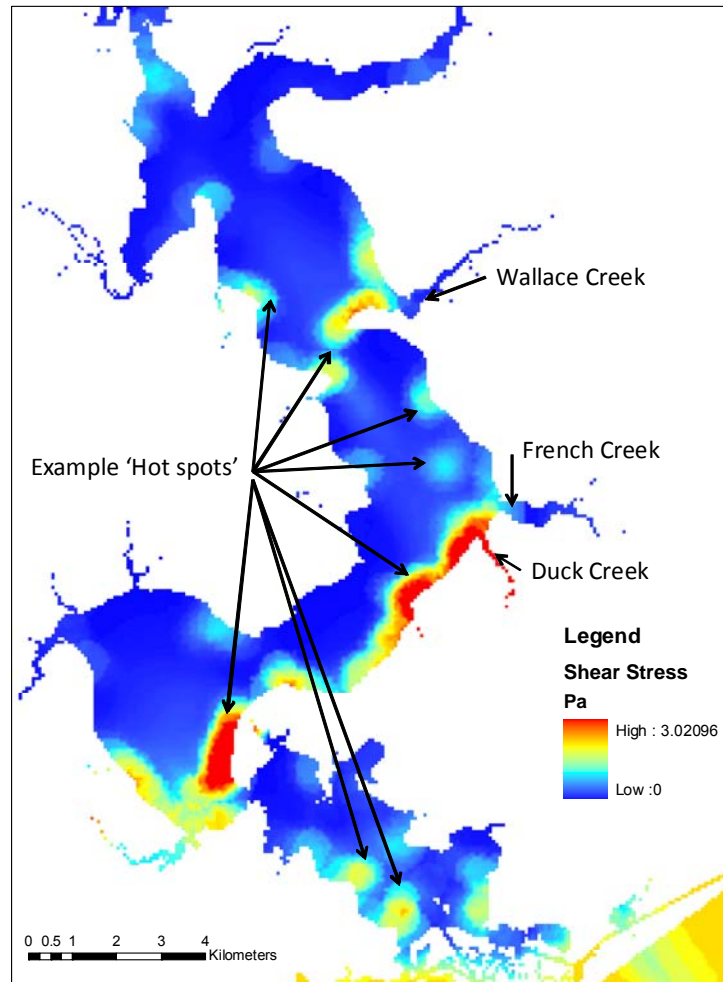

Figure ES-4. Sea floor shear stress chart (Pa = pascals) of NRE for top 5% wind events 2007–2010.

- By combining erosion rates from historical aerial photography and wave energy climates, we have developed an understanding of shoreline vulnerabilities and ranked habitat types for mitigation actions. Of the three natural shoreline habitats occurring in the NRE, swamp forests (6%) occur only in the lowest wave energy climates and will not require substantial protection from chronic wave events. Marsh habitats (21%) generally occur in lower wave energy regimes, but some in more energetic settings have exhibited some of the highest shoreline erosion, and thus those marshes will require protection or restoration. Sediment bank habitats (54%), the most

frequently encountered natural habitat in the NRE, exist across the widest range of wave energy regimes, and those in the highest wave energy regimes consistently exhibit the highest shoreline erosion. In addition, erosion rates may have accelerated in recent years. However, shore-protection measures should be considered for vulnerable sediment bank shorelines only if Base managers plan development on the adjacent uplands.

▪ Characterization of the shoreline on both sides of the ICW identified salt marsh habitat (80%), sediment banks (19%) and modified (1%) shoreline; no swamp forest habitat was identified. Protection of the ICW marsh habitats, including several actively used splash points (Numbers 6, 9, 10, 11, and 12), may require a combination of shoreline stabilization, marsh restoration, and vessel wake controls (e.g., no wake zones) to constrain erosion and increase the sustainability of these areas.

▪ Mesocosm experiments of above-ground *Spartina alterniflora* biomass across marsh elevation gradients demonstrated a large positive effect of fertilizer on marsh growth, and fertilized plots exhibited significantly higher increases in surface elevation change than control plots. Together, these results will improve our ability to predict the sustainability of salt marsh habitat to sea-level rise and make management recommendations to minimize marsh loss.

▪ The net result of tidal versus watershed controls on the movement of nutrient-rich water from the marsh into estuary waters is affected by human activities that impact (1) the tidal amplitude in the NRE that will directly affect the magnitude of nutrient drainage in all marshes; and (2) the elevation of the shallow groundwater level that will affect the drainage fluxes of water and nutrients only in fringing marshes of the upper NRE (i.e., French Creek), but not in more tidally influenced marshes. For all marshes, however, the potential remains for changes in shallow groundwater elevation to influence the boundary between salt and fresh water in the marsh subsurface that ultimately affects changes in marsh plant production and decomposition.

▪ Refinement of the Marsh Elevation Model 2 (MEM2) is progressing with the collection of additional data during 2010 on key parameters that have not been available previously for MCBCL salt marshes. The results suggest that the ICW is destabilizing the adjacent salt marshes and that frequency distributions of marsh elevation appear to be diagnostic for salt marsh condition. From these findings, a new conceptual model for the salt marshes bordering the ICW was developed to account for differences in marsh elevation and rates of accretion. This new conceptual model further supports the influence of the ICW on sediment dynamics and health of the adjacent salt marshes.

ES-6. Coastal Barrier Module Summary

The Coastal Barrier Module study area includes Onslow Island, from the New River Inlet to Browns Inlet, and the newly added stations on Bear Island that serve as control sites (i.e., relatively free from human disturbance). This ecosystem encompasses the shallow subtidal and intertidal shore face, the tidal inlet, the backshore beach, dunes, shrub zone, the incipient maritime forest, and washover sand flat habitats. These habitats are defined by intrinsic ecological processes, but are linked by sediment transport, nutrient exchange, and biological uses, each of which undergoes substantial changes over multiple time scales. Onslow Island is a critical part of the Base's amphibious assault training program and, as a result, warrants management strategies that will enable continued training use of the beach, while managing it as a sustainable ecosystem. Understanding erosion-rate variability due to various natural and human activities will help improve management of the coastal barrier and preserve the integrity of the amphibious maneuver areas, including Onslow Bay (Military Driver #1). In addition, the Coastal Barrier Module's monitoring and research programs will help the Base comply with the ESA (Military Driver #4) by understanding the habitat quality needed to sustain sea turtle and shorebird use of the island.

Major accomplishments and benefits to the Base during this past year include the following:

- The Onslow Island shoreline has a sinusoidal morphology, with southern and northern embayments separated by a centrally located headland, where an Oligocene rock ridges intersects the island, and data show that beaches are consistently the steepest at the headland. There is a strong correlation between beach gradients along Onslow Island and the maximum depth of sediment erosion during a year. This is likely due to the higher wave energy that impacts steeper beaches at the headland than at low-gradient beaches at the embayments. The headland–embayment morphology plays a more significant role in controlling the along-beach variations in beach erosion than do military training activities.

- Shoreline movement and volume change in the middle part of the barrier island are more highly variable, fluctuating between accretion and erosion in terms of shoreline movement, than either the southern or northern ends of the island. Areas along the northern one-third of the island are losing more than one dump-truck load (7.6 m^3) of sand per day. The far southern end of the island is moving seaward (accreting) in the yearly data set, but eroding in the decadal data set. This recent accretion is likely trapping sediment from adjacent areas in the military training area to the north that is eroding rapidly.

- Barrier island overwash is a primary mechanism for transporting sediments onto and/or behind the barrier surface, supporting back-barrier marsh habitats, and maintaining barrier islands in the face of rising sea level. Based upon the average cumulative thickness of distinct washover sediment layers within sediment cores and the surface area of the active overwash region, we estimate that the volume of washover deposits equals 30% of the active overwash complex, or 11% of the entire relevant-sand prism of southern Onslow Beach. These data indicate that overwash plays a significant role both in maintaining Onslow Beach and in providing the necessary sediment supply to fragile, back-barrier ecosystems.

- A run-up and surge model was modified for Onslow Beach and used to identify areas of the barrier island most vulnerable to inundation and overwash during events such as Tropical Storm Ernesto (**Figure ES-5**). This model shows that the southern end of the island (0 m–4,000 m distance alongshore) is more vulnerable to overwash than the northern end (4,000 m–13,000 m distance alongshore) because of differences in the height of the dune crests and effects of surf-zone bathymetry to wave energy. Specifically, the model results reveal that the height of the run-up elevation is spatially variable and is sensitive to localized morphology and depths across the surf zone. Being able to model the areas vulnerable to run-up and surge allows Base managers to determine which areas will be inundated during storm events.

- The stratigraphy of sediment cores collected on the northern end of Onslow Island indicates that this part of the barrier island was less stable in the geologic past and dominated by overwash. These thick, sandy, overwash sediments could have served as a localized source for sand that contributed to this part of the barrier becoming more stable than the southern portion of the barrier in the geological past during a period when the rate of sea-level rise decreased. The cores from the highly erosive southern end of the island suggest a persistent, unstable island continually dominated by overwash processes and an eroding shoreline and suggest that erosion of Onslow Beach was occurring long before MCBCL was established.

- Detailed analysis of 30 years of sea turtle data collected by MCBCL has revealed several important factors related to Base management of these endangered species. First, both the total number of nesting events and the number of nests laid decreased spatially towards both inlets (New River and Browns Inlets). The relatively high proportion of successful crawls in the recreational area, located in the center of the island, suggests that the Base's efforts to limit light pollution and human disturbance are successful. Second, the mean emergence success rate (ESR) for sea turtles declined significantly from 1982 to 2009 on Onslow Beach. However, the ESR for the Base-relocated nests was significantly higher than for natural nests in part resulting from the ability of Base staff to consistently select superior locations for relocating sea turtle nests originally laid in the military training area.
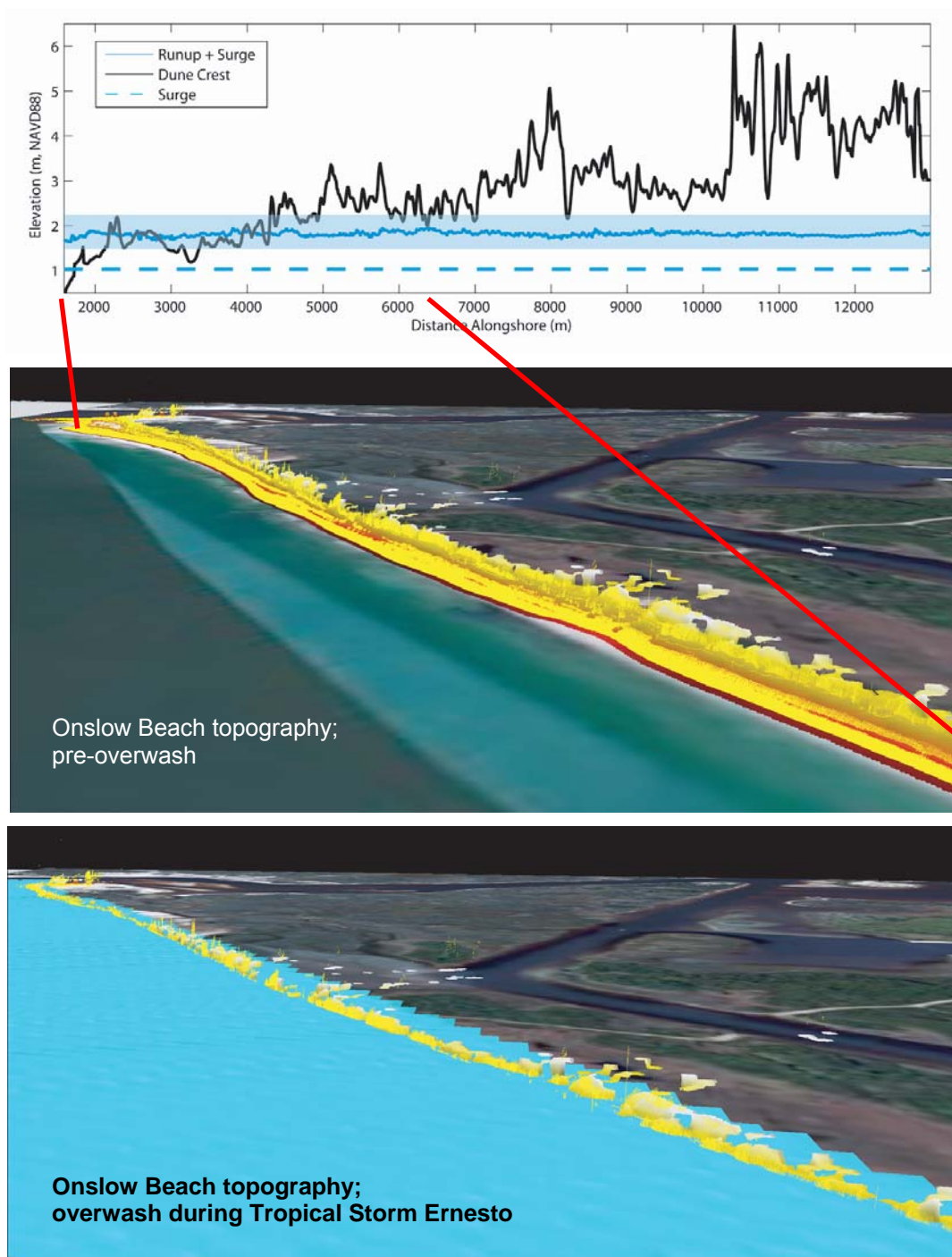
Figure ES-5. Results of the run-up and surge model (upper panel) developed for Onslow Beach.
This model simulated inundation of areas before (middle panel) and after (lower panel) passage of Tropical Storm Ernesto. The results are shown for the southern end of Onslow Island (0 m–4,000 m distance alongshore).

▪ Sampling to date has not revealed any negative effects on surf fish abundance relative to anthropogenic disturbances on Onslow Beach. The greatest richness in surf fish species was observed in samples collected from the recreational beach zone. In addition, there has been no indication that abundance of the food for surf fish and shorebirds (intertidal invertebrates) has been adversely affected by anthropogenic activities.

- A study of eolian transport of sand across Onslow Island to the backbarrier marshes was initiated with the design and development of a novel sediment collection device and submission of a methods paper for publication.
- Three years of data (2008–2010) were used to calculate an overall apparent adult survival rate of 82% for Wilson's plovers. Although there are no other studies of Wilson's plover survival rates to which we can compare these data, this survival rate is very similar to what has been documented for a similar species (i.e., piping plover). Although we cannot know for sure whether Onslow Beach is serving as a regional source or sink for the Wilson's plover (without data on emigration to other sites), these data, along with our productivity and in-season chick survival estimates, suggest that the population at Onslow Beach is likely stable.

ES-7. Terrestrial Module Summary

The terrestrial ecosystem at MCBCL encompasses the gradient of vegetation from the salt marsh at the estuary margin, through the brackish and freshwater marsh, to the longleaf pine (*Pinus palustris*), savannas, and pocosins (shrub bog) that dominate MCBCL's terrestrial environments. Variation in the biota and ecosystem processes along these gradients is driven by variations in hydrology, soils, and fire behavior. The main objective of the Terrestrial Module is to provide a better understanding of the functioning of the entire terrestrial ecosystem to enable MCBCL managers to better integrate military training with natural resources management objectives, such as forest sustainability, habitat restoration, and endangered species recovery. The Terrestrial Module's monitoring and research program is designed to provide baseline information on the land-use and land-cover changes that have occurred at MCBCL over the past 25 years and to monitor future changes throughout the duration of the DCERP. Other objectives are to conduct focused studies on existing loblolly pine (*Pinus taeda*) habitat that are being restored to longleaf pine habitat by MCBCL natural resources managers to support recovery of the RCW (*Picoides borealis*) and examine the effects of habitat management for RCWs on the avian community diversity as a whole. The results from these programs can be applied by MCBCL staff to enhance future uses of MCBCL ranges and training areas (Military Driver #3) and to ensure that MCBCL supports required military training activities, while complying with the ESA (Military Driver #4).

Major accomplishments and benefits to the Base during the past year include the following:

- A Greenness Change Analysis was conducted for MCBCL to identify areas with varying vegetation loss (completed 2009) or vegetation gains measured as greenness gain (completed 2010). With the completion of the greenness gain analysis, detailed information exists on when a change occurred, and this can then be used to create a change trajectory over time for both loss of vegetation and vegetation regrowth for all MCBCL lands. This is a flexible information data set that can be used to look at vegetation losses and gains in terms of specific time periods or to track changes through all five change periods from 1984 to 2009.
- Overall, MCBCL has experienced a 7.2%–10.6% (3,648 ha–5,373 ha) permanent vegetation loss between 1984 and 2009; however, up to 37.8% (19,060 ha) of the vegetation on the Base has been reduced or removed at some time during this period. Conversely, 3.5% (1,789 ha) of MCBCL lands have experienced a "persistent" gain in vegetation since 1984. For the most recent change analysis period (2007–2009), 1.6% of the surface area (791 ha) of MCBCL lands experienced significant loss or removal of vegetation in concentrated areas, likely representing new infrastructure construction related to the Marine Corps' Grow the Force Campaign.
- Vegetation monitoring plots are distributed across different vegetation cover types and soil characteristics at MCBCL. More than 450 individual plant taxa were encountered among the 131 monitoring plots, with an average of 42 species in each 0.1-ha plot. The range in species richness among plots was large, ranging from 9 to 119 species per 0.1-ha plot. Analyses of plots dominated by pond (*Pinus serotina*), loblolly, or longleaf pines indicate that disturbance, stand maturity, soil moisture, and chemistry account for considerable variation in species composition.

- Comparison of longleaf pine plots sampled in both 1993 and 2009–2010 indicates that these ecosystems tend to become more diverse and species composition becomes more representative of mesic sites with regular prescribed burning.
- In the 45 plots where both vegetation and bird communities were sampled, plant and avian species composition was found to be highly correlated (**Figure ES-6**). Both vegetation composition and avifaunal communities showed partitioning and were compositionally different among longleaf pine, loblolly pine, and high-pocosin sites. The overlap between the two communities suggests that the composition of avifaunal communities is tightly correlated to the differences in understory vegetative composition that can emerge in the different mature pine stands, indicating that future efforts aimed at recovering avifaunal species of concern may depend upon the recovery of understory plant communities.
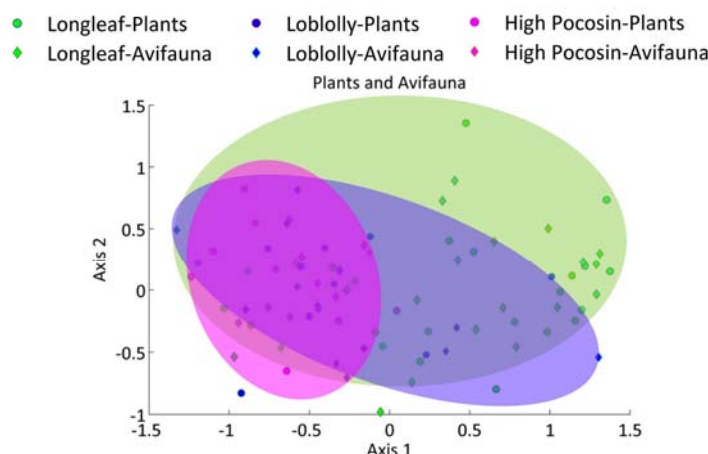

Figure ES-6. Non-metric multidimensional scaling (NMS) ordinations of understory vegetation composition and breeding bird species composition at 45 pine-dominated monitoring plots.
Pink = high pocosin plant and avifauna communities, blue = loblolly plant and avifauna communities, and green= longleaf plant and avifaunal communities.

- Bird community composition across a wide variety of forest habitats at MCBCL was evaluated to address concerns regarding whether managing forests for a single endangered species, the RCW, has a negative impact on other at risk species and/or the avian community as a whole. Preliminary results suggest that both species richness (the number of species) and species diversity (the relative abundance of the species present) increased as RCW habitat quality increased. This is clearly the case for species associated with open pine habitats such as the red-headed woodpecker (*Melanerpes erythrocephalus*) and the Eastern bluebird (*Sialia sialis*). Many pine canopy bird species such as brown-headed nuthatches (*Sitta pusilla*) and pine warblers (*Dendroica pinus*) are also favorably affected by improved RCW habitat. Some species associated with broadleaved hardwood forest were slightly negatively affected (e.g., the Carolina wren [*Thryothorus ludovicianus*]), whereas others were positively affected (e.g., tufted titmouse [*Parus bicolor*]) by improved RCW habitat. In general, these results support the hypothesis that the RCW is a good umbrella species for the management of overall avian diversity in longleaf pine habitats.
- The Bachman's sparrow (*Peucaea aestivalis*) is an at-risk species of special concern to MCBCL that, like the RCW, is associated with open pine habitat. It is particularly important that management for the RCW, which is designed to produce open pine stands with well-developed ground cover, should also benefit Bachman's sparrow. Our analysis indicates that this is the case with sparrow occupancy increasing as RCW habitat quality improves (and in fact the species does not occur at all in the lowest RCW habitat quality category).

ES-8. Atmospheric Module Summary

The Atmospheric Module's monitoring and research programs were designed to describe and improve the understanding of critical pollutant transport (primarily ozone and particulate matter [PM]) and advection processes that are subject to complex land–sea breeze circulation patterns and more regional synoptic forces. The research program focuses on the areas of prescribed burning and nitrogen deposition. In conjunction with the ecological work of the Terrestrial Module, the prescribed burning research will inform MCBCL smoke management planning by quantifying and parameterizing emissions from different longleaf pine restoration treatments. In addition, the Atmospheric Module is collecting data to estimate the total atmospheric nutrient loading (to open-water surfaces of the NRE and to vegetation surfaces of MCBCL lands), which is critical information needed for developing a nitrogen budget for the NRE. The input of nutrients and potential pollutants via atmospheric deposition interacts with key terrestrial and aquatic ecological processes occurring at MCBCL. Inputs of these nutrients and pollutants can come from local (on Base) or regional (off Base) airshed sources constrained by predominant wind patterns. This atmospheric loading estimate will, in part, address the MCBCL military driver to ensure that the Base supports continued military training activities, while complying with the CWA (Military Driver #5).

Major accomplishments and benefits to the Base during 2010 include the following:

- For 2003–2009, the total inorganic nitrogen (N) deposition at Hofmann Forest (approximately 10 miles northeast of MCBCL) was approximately 27 kg N/ha, or an average of 3.8 kg N/ha/yr. For MCBCL, the cumulative total nitrogen deposition among the four collectors ranged from 3.5 kg N/ha to 5.5 kg N/ha for 2010 for an average of 4.4 kg N/ha/yr, which is similar to the deposition at Hofmann Forest.
- In collaboration with Research Project T-1, prescribed burning emissions measurements in two study areas allowed the comparative evaluation of the effect of fuel condition (hydroax removal of the midstory versus untreated control) on aerosol emissions. Based on preliminary results, it appears that more of the available material is being consumed when fuel is hydroaxed, especially under wetter fuel conditions. Particulate species emissions from drier fuels were systematically higher than for wetter fuels, and the flaming of dry hydroaxed fuel tended to cause the highest emissions factors for almost all PM species. The land management practice presenting the best compromise for meeting both objectives of effective fuel reduction and direct PM emissions reduction, therefore is to burn moist hydroaxed fuel.
- Portions of $PM_{2.5}$ are formed through secondary atmospheric processes (via complex heterogeneous gas-to-particle conversion reactions), whereas other portions are emitted directly into the atmosphere from various sources (e.g., heating, wood-burning, transportation). As indicated by ozone, the proximity of MCBCL to the ocean increases the potential for atmospheric particle formation, thereby increasing the ambient $PM_{2.5}$ mass concentration. However, our findings indicate that average $PM_{2.5}$ concentrations are higher at sites farther from the ocean, suggesting that the secondary (atmospheric) formation of $PM_{2.5}$ plays only a minor role in the local burden of $PM_{2.5}$ at MCBCL.
- Applying fuel-specific emissions factors to the 2009 annual total managed forest area revealed that prescribed burning emissions of all criteria pollutants from either fuel type (hydroaxed versus non-hydroaxed controls) are significantly higher than from any other combustion source category operated on Base. This illustrates the importance and value of developing and implementing measures to effectively manage prescribed burning emissions.

ES-9. Data and Information Management System

To support the data management needs of DCERP and the complex and voluminous environmental data being collected and used for the program, it is crucial to make research results, monitoring information,

and other data accessible to the DCERP Team. The DCERP DIMS is a database-driven Internet system that provides a means to access and manage the DCERP data collections and provides useful and scientifically sound data and information in a framework to support ecosystem-based management tools. To accomplish these tasks, the DCERP DIMS consists of MARDIS, the Document Database, public and Collaborative Web sites, and a Geographic Information Systems Mapping Tool for MARDIS.

Major accomplishments and benefits to the Base during 2010 include the following:

- The Data Management Module (DMM) staff continued to work with researchers to facilitate the uploading of data-specific attributes to MARDIS. As of March 2011, these efforts have increased the number of archived files to more than 16-million records and 25 data sets.

- The DMM staff completed the development of advanced tools for data discovery and visualization to allow all MARDIS users to easily put DCERP data into practical use, such as allowing users to query data by data set, view various statistical results by parameter, and filter a parameter further based on value limits (e.g., screening water quality data parameters against state water quality standards). These enhancements help increase the usability of MARDIS and the DCERP data for both the Base staff and DCERP researchers.

- The DMM staff designed and implemented the Document Database as a new component within MARDIS. This database provides an archive for unstructured data products such as maps, photographs, data files, and other documents that cannot be stored as structured data. The Document Database serves as a searchable repository for all of the DCERP Team's final products, including technical reports for the Base, program reports for SERDP, and peer-reviewed journal articles. Metadata associated with each final product are searchable to facilitate rapid document retrieval.

- The DCERP public Web site was redesigned to include additional information and graphics to be more user friendly and informative. Information about the monitoring and research projects for each of the five ecosystem modules and additional details about MARDIS were added to enhance the public outreach aspects of the program.

- The DMM team is refining a decision-support system (DSS) prototype that will use a geographic information systems (i.e., ArcGIS)–based land-use suitability tool that will allow for the assessment of down-stream effects of potential land-use changes. This prototype is an example of the types of DSS tools designed to incorporate DCERP monitoring and research findings with DCERP and MCBCL geospatial data layers that could be developed for use by MCBCL staff to make ecosystem-based management decisions. To build a DSS tool for the Base, efforts are focused on the development of the framework to illustrate the possibilities of integrating models with MARDIS.

ES-10. Summary

Implementation Year 3 of DCERP has resulted in significant findings regarding ecosystem function and structure in areas such as tributary and estuarine water quality, air emissions associated with prescribed burning, terrestrial plant and avifaunal community structure, barrier island morphology, and accretion–erosion dynamics in both the coastal barrier and associated coastal wetlands. Significant findings and progress throughout 2010 were reported by DCERP researchers at the TAC meeting in March 2010, which included the TAC members and MCBCL and SERDP staff. This meeting provided review and scientific evaluation of each research project's achievements, future direction, and relevance to Base management needs. In addition, DCERP researchers and the DCERP OSC have regularly briefed the MCBCL staff on current monitoring and research efforts to keep the Base staff informed on DCERP activities and obtain their feedback to better understand Base management needs. Finally, the large number of presentations at various scientific forums and conferences and the submission of numerous

manuscripts to peer-review journals have informed the wider scientific community about DCERP's significant research findings.

ES-11. Next Steps

In the coming year (2011), many of the DCERP researchers will continue to incorporate the data collected over the past 4 years into their cross-module modeling efforts. These models will provide better information on coastal hydrodynamics and forcings affecting the coastal barrier, estuary, and wetlands and will define estuarine circulation patterns, flushing rates, and exchange patterns. Models will also help refine the nitrogen and sediment loading to the NRE, and provide revised predictions of tidal and storm-driven water levels throughout the estuary to assist with studies on marsh elevation and shoreline erosion, as well as areas of high sediment resuspension. Models will also identify areas prone to erosion and accretion on the barrier and the spatial extent of coastal inundation will be forecast using various storm scenarios.

The Aquatic/Estuarine Module will continue analyses of phytoplankton productivity and benthic microalgal processes on the NRE and loadings of nutrients and sediment from the tributary creeks and the New River and their resuspension in the NRE during storm events. The Estuarine Simulation Model (ESM) and the watershed models will be used to conduct a simulation analysis with a focus on overall NRE ecosystem function and the impacts of natural and anthropogenic stressors on the system. The ESM will provide the Base and regional managers with a tool for understanding the response of the estuary to future natural and anthropogenic impacts and will facilitate the development of water quality management plans (e.g., Total Maximum Daily Loads) for the system.

The Coastal Wetlands Module will develop a Shoreline Management Plan to identify the Base's most vulnerable estuary shorelines and recommend management measures to protect them. Researchers will also calibrate and conduct final testing of the MEM2 with data from the NRE coastal fringe marshes to determine the marsh elevation "tipping point" and make final management recommendations based on model simulations.

The Coastal Barrier Module will continue to monitor physical and biological parameters (fish and invertebrates) on Bear Island (reference site) and on Onslow Island. All monitoring data will be integrated to address top-down and bottom-up drivers affecting the shorebirds and other species of concern (sea turtles) on the barrier island. Models will be completed to predict areas of the barrier prone to wave run-up and inundation under various storm scenarios. Results of these models will be integrated to provide both a long-term geological perspective and a short-term perspective of how the barrier island is changing, culminating in ecosystem-based recommendations to the Base for extending the sustainability of the amphibious training area.

The Terrestrial Module has determined the vegetative and avifaunal diversity across MCBCL and will determine the complementary diversity of insects across some of the same research plots. Studies on the impact of forest management practices, including midstory removal and prescribed fire, on vegetation structure and air emissions will be completed. In addition, a comprehensive analysis will be finalized using the bird census study data from both the 2009 and 2010 studies of RCW habitat quality and avian community structure. Lastly, this module will continue to evaluate more targeted land-use and land-cover change patterns on Base lands to support other DCERP modules.

The Atmospheric Module will complete evaluations of the differences in particulate and gaseous emissions from both flaming and smoldering phases of prescribed burns conducted on three additional pairs of research plots managed with mechanical fuel treatments (e.g., hydroaxing) compared to untreated sites. The results obtained from co-located terrestrial treatment plots will assist Base managers in evaluating the effects of forest management practices on prescribed burning emissions and restoration

targets and assist in the development of a Smoke Management Plan for the Base. Continuation of the air monitoring network will provide additional information on air quality to place Base lands within the context of the wider regional airshed.

The DMM staff will continue to provide support for all modules in uploading structured monitoring and research data to MARDIS and capturing and archiving final DCERP products in the Document Database. A process for designing a DSS framework and prototype of a model to test the framework will be developed using data from MARDIS and MCBCL to better inform Base management decisions.